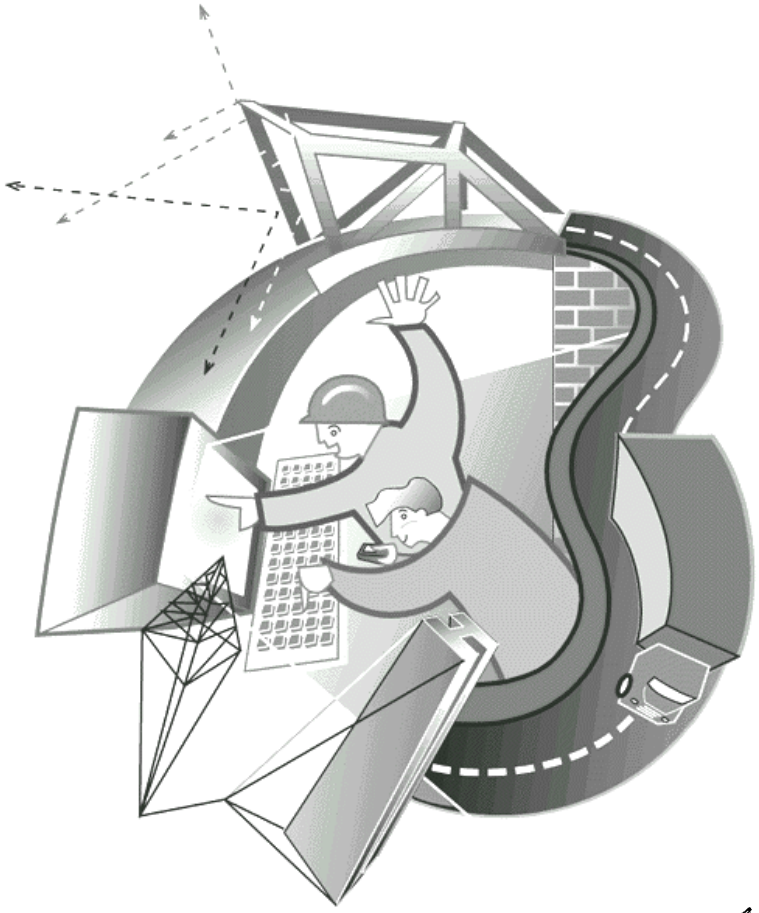
Bridge Builder®

A Program for Exploring Structural Engineering

Build and Test Bridge Designs on Your Computer



Pre-Engineering Software Corporation

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presents

BRIDGE BUILDER®

(Windows® version)

A Program For Exploring

Introductory Concepts in Engineering

Written by: Robert A. Wolf III, P.E.
Edited by: Mary Anne Wolf, P.E.
Cover by: graphics, etc..., & Bret Guidry
Illustrations by: Bret Guidry

System Minimum Requirements:
IBM Compatible 80386, 4 megs RAM
16 color VGA, Microsoft Compatible Mouse
Microsoft® Windows® 3.1

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INSTALLATION & SETUP

Part I - Installing the Software

Verify that there is at least 5 megs of free space available on your hard drive. *It's a good idea to reserve an additional 10% to 20% of your drive's capacity for general work space.*

To install Bride Builder, load the Bridge Builder CDROM in the drive. The "INSTALL" program should run automatically. If "INSTALL" does not autorun, click the "Start" button, select "Run", then type "X:\INSTALL" (where X represents your CD ROM drive letter). Click "OK"

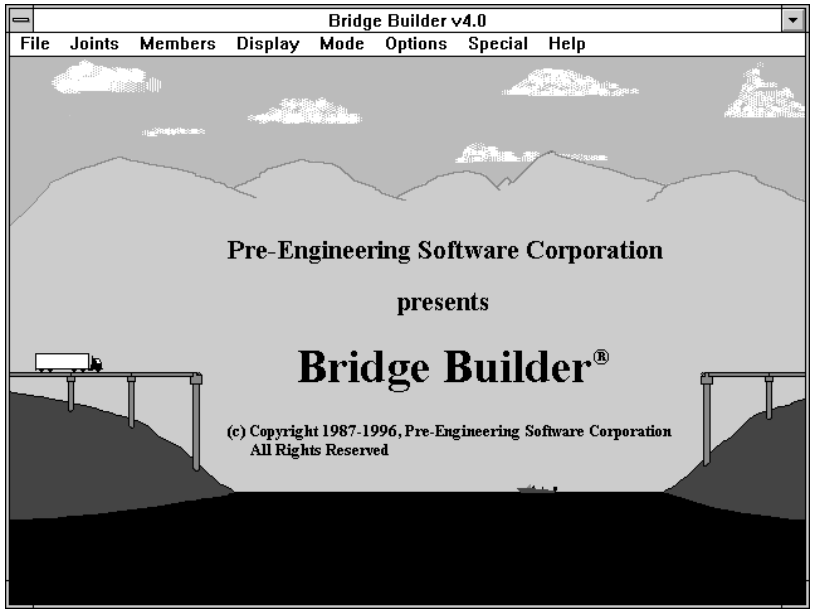
Configuring the Software for Sound

The install routine in this chapter automatically configures Bridge Builder to work with an MCI compatible sound card. You may turn the sound off by de-selecting "Sound" from the "Special" menu.

Software Removal

To remove Bridge Builder, run the uninstall routine found in the BB4 folder.

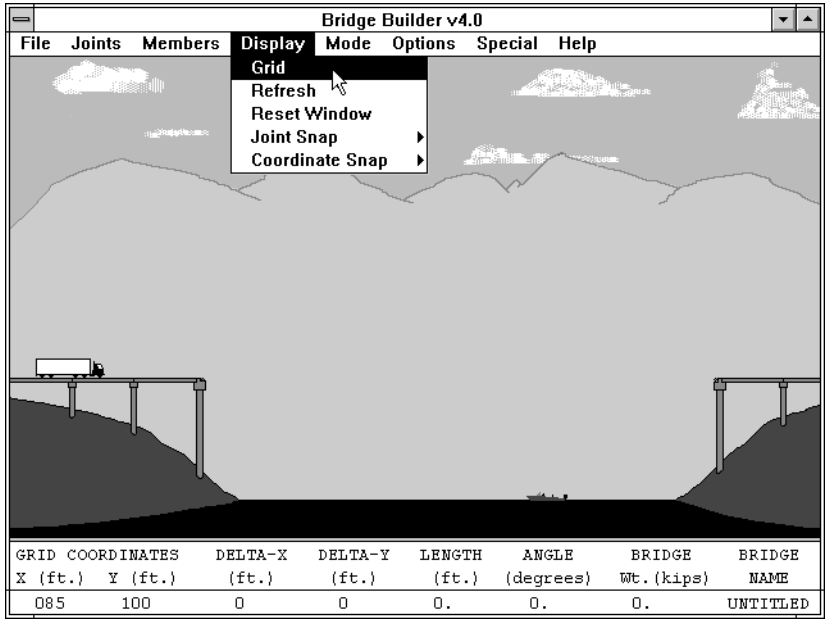
QUICK START



The purpose of this chapter is to introduce the Bridge Builder commands necessary for running the program.

Note: Bridge Builder will attempt to detect and use a sound card. If you do not wish to run the program with sound, after the program starts, pull down the "Special" menu and toggle the "Sound" option to turn the sound off.

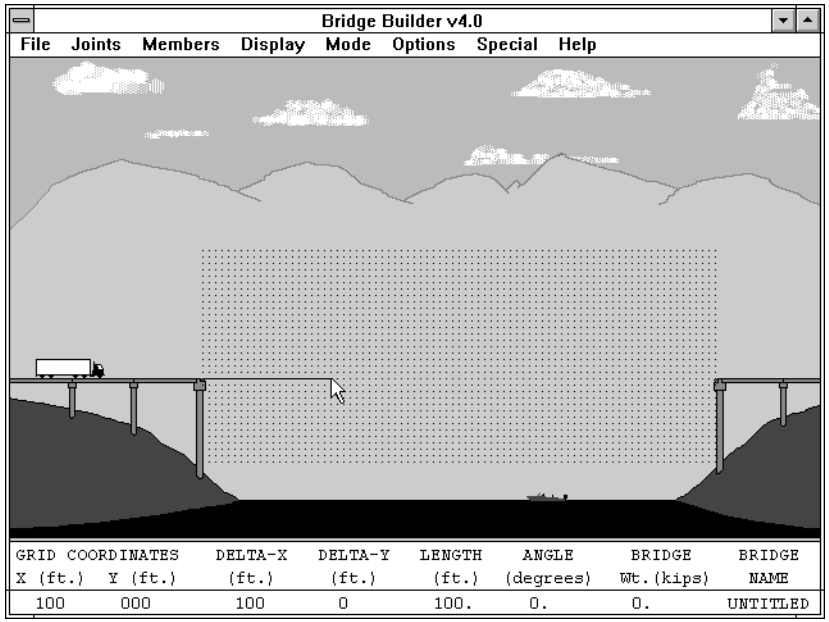
To start the program double click the "Bridge Builder" icon in the "Pre-Engineering Software" group or, for Windows 95 users, click "Start", then point the cursor to "Programs", "Pre-Engineering Software" and then "Bridge Builder v4.0". Release the mouse button.



After the introduction & copyright information clears, the window will appear as shown above. The program is already in the "Build" "Mode". Before starting to draw your bridge, it's a good idea to select "Grid" from the "Display" menu.

Note: *This example problem uses the program's start up defaults. If you are not just starting the program, verify that the "Default Size" under the "Members" menu is set to "5".*

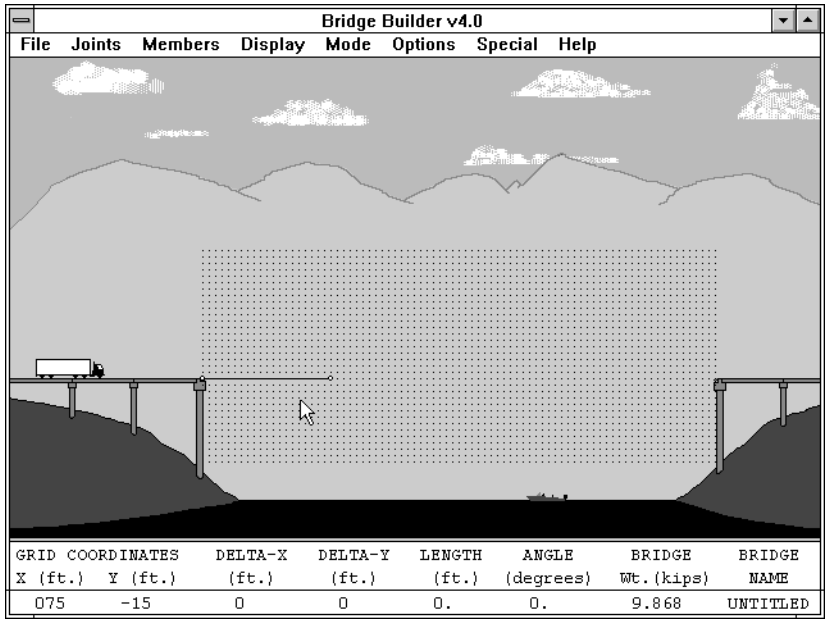
Let's start drawing a bridge!



Move the cursor arrow to point to the top right corner of the left abutment. Make sure that the X & Y coordinates read X=0,Y=0, then press and hold down the left mouse button.

Now without releasing the left mouse button, move the mouse to the right until the cursor arrow points at the coordinate X=100, Y=0. Now release the mouse button.

That's it. You have just drawn the first member of the bridge.



In general, this is the way to add members to the bridge. Here once again are the steps involved:

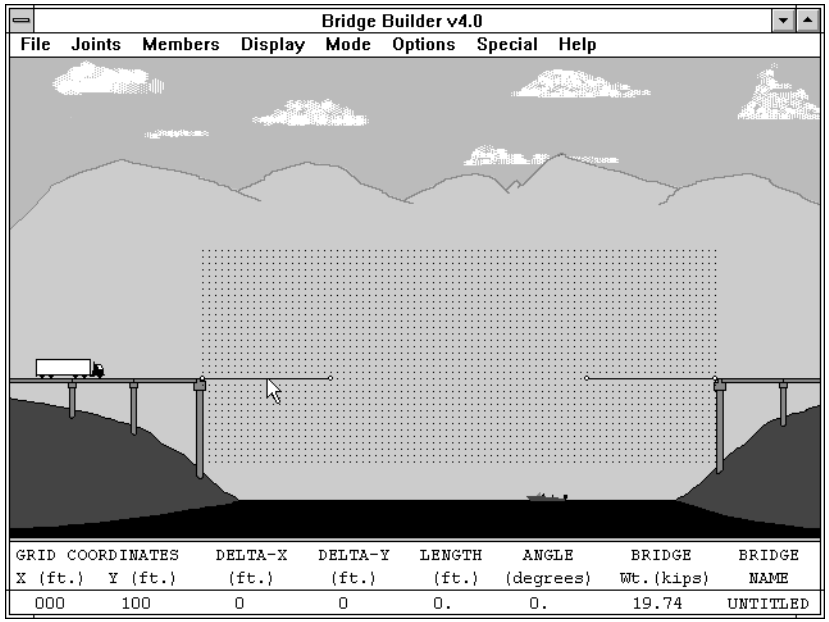
1. Verify that "Build" is selected under the "Mode" menu item.

2. Move the mouse arrow to the position where you want to start the member.

3. Press and hold down the left mouse button.

4. Move the mouse arrow to the position where you want to end the member.

5. Release the mouse button.

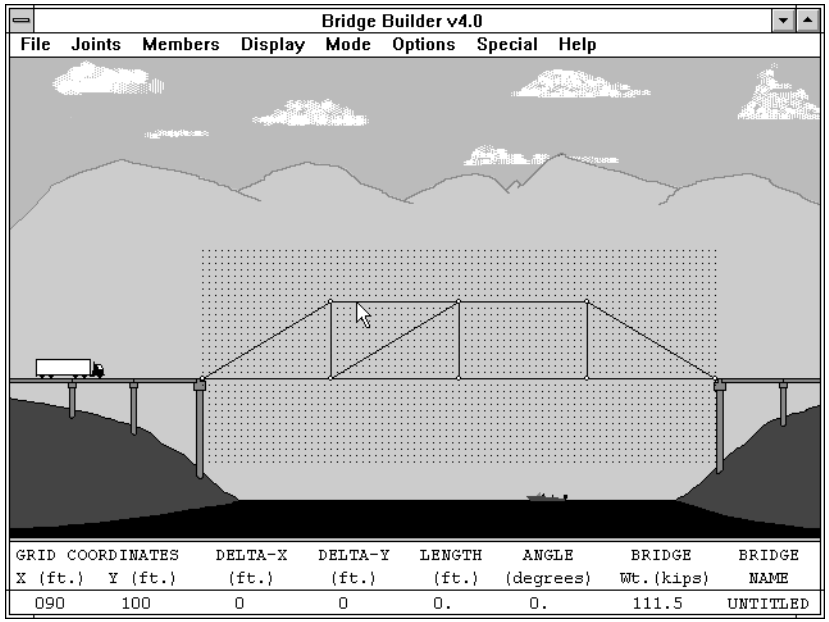


But there is another way! You can "Reflect" a previously drawn member.

Select "Reflect" from the "Members" menu. Now position the mouse pointer over the member just drawn. Click the left mouse button.

Wow! You just drew another member of the bridge. Most of the bridges that you draw will be symmetrical about the center of the span. The "Reflect" option allows you to take advantage of this fact.

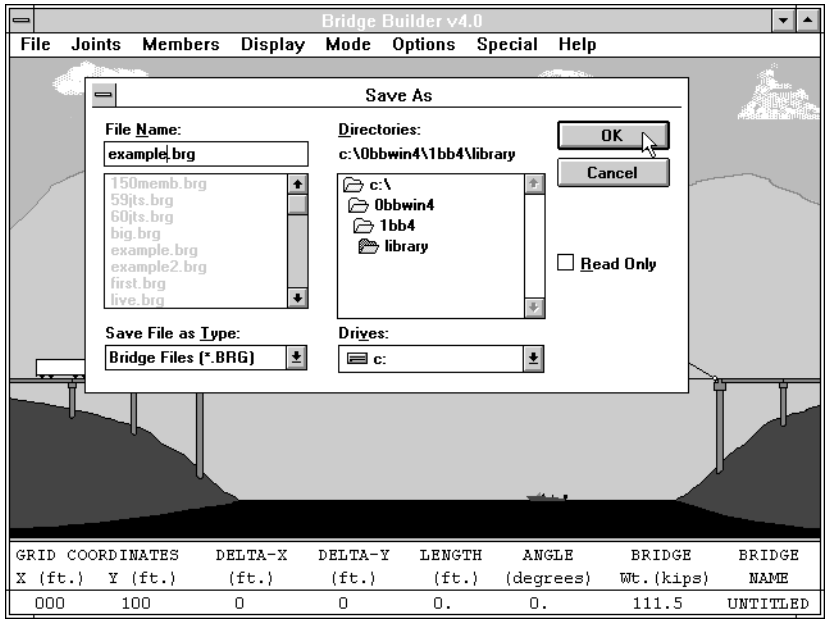
Let's continue building the bridge. Select the "Build" option from the "Mode" menu.



Draw the additional members as shown above (The top of the bridge is at Y=60). To do this, draw the members to the left side of the center span and "Reflect" the members required to complete the bridge. (Note: leave out one diagonal as shown.)

The "Reflect" option will work from left to right and also from right to left. So, if you want to draw the initial member right of the center span and reflect them left, you can.

The reflect member option will not work on a member that crosses the center line of the span.

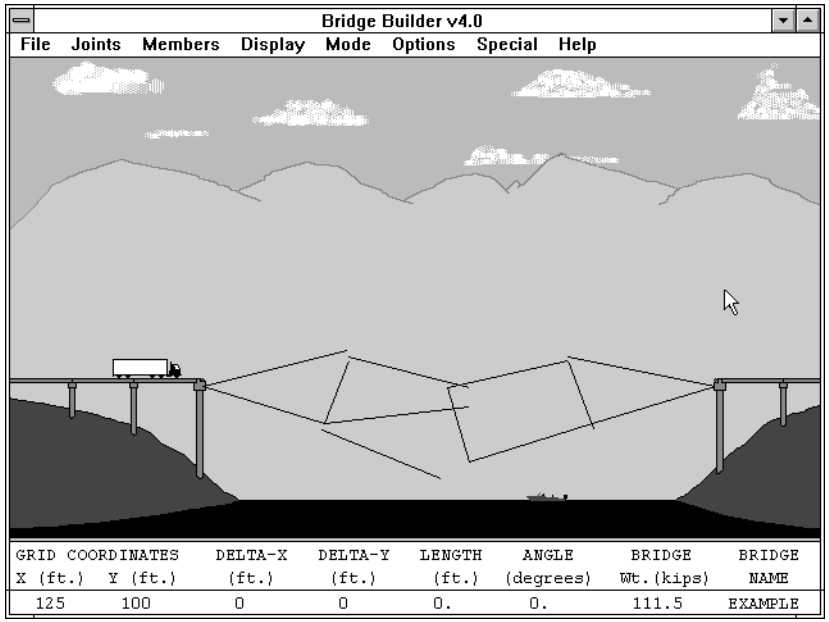


Let's save the bridge before analyzing it.

Select "Save As.." from the "File" menu. Double click the Library directory and enter "EXAMPLE" for the name of the bridge. Click "OK".

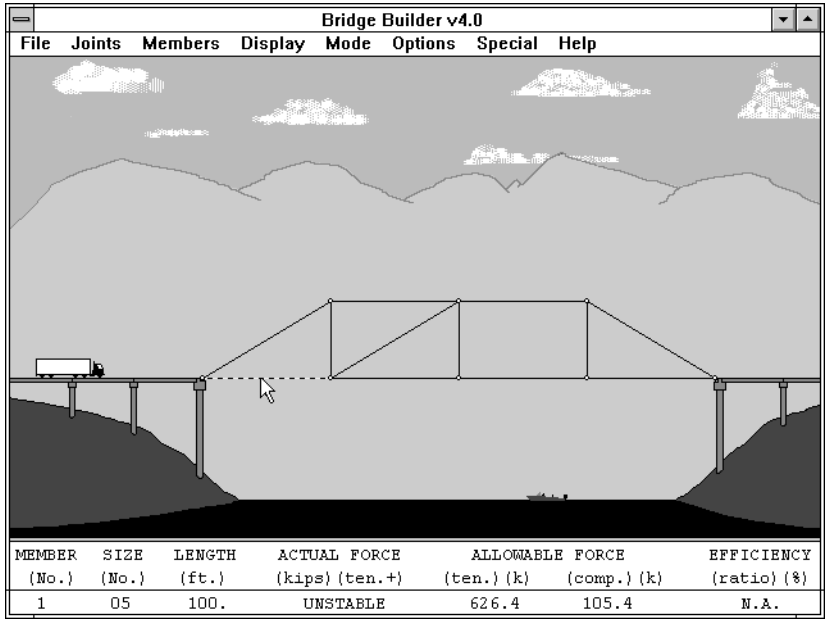
We are now ready to analyze the bridge. Pull down the "Mode" menu and select "Animate". This will test the bridge by rolling a 40 ton truck along the roadbed.

Turn the page to see what happens!



The truck did not make it across! In fact it didn't even make it to the bridge. Why?

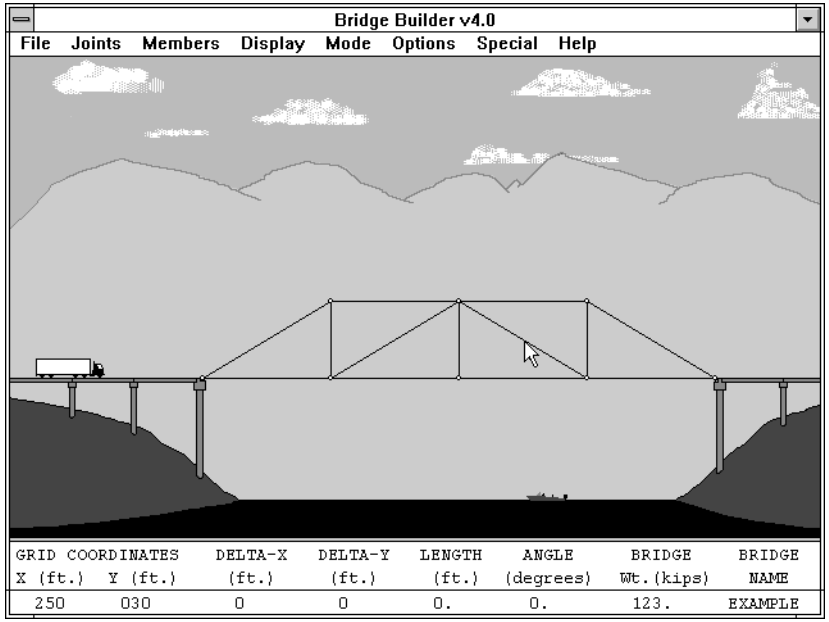
First, look at the geometry of the bridge to make sure that it is composed of triangular shapes. This bridge is not composed of all triangles. Therefore it is unstable. This means that the bridge can't even support its own weight. That's why the bridge fell before the truck even reached the bridge.



Now look at the results screen and check the individual member results.

The results screen is used to determine what to do to strengthen the bridge. Notice in this case the actual force in the members is unavailable and reported as "UNSTABLE". The actual force is the force that was produced in the member as a result of the truck on the bridge. In this case the bridge could not take any load. These results indicate a geometric instability problem.

Let's add the missing diagonal.



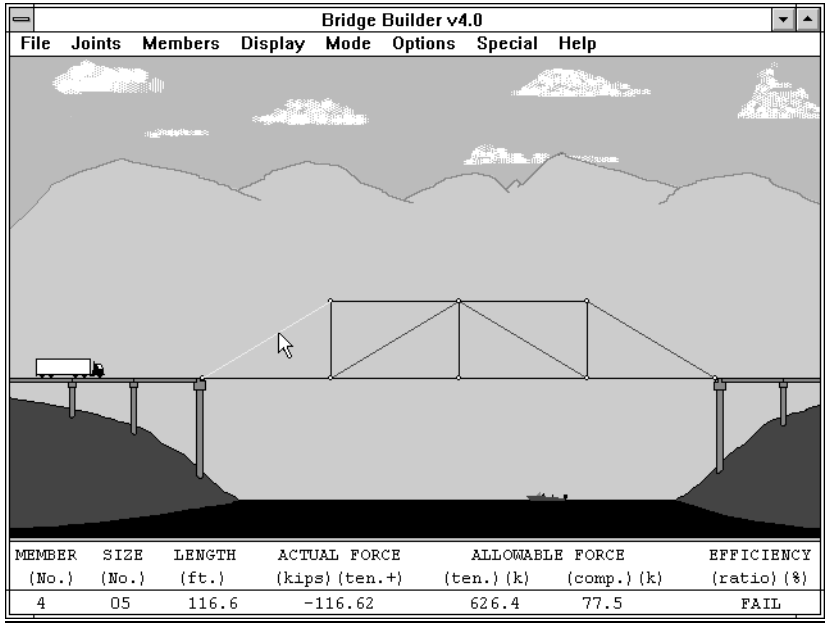
Draw the diagonal as shown above.

Let's save this version of the bridge before analyzing it. Pull down the "File" menu and select "Save".

Now let's analyze it. Pull down the "Mode" menu and select "Animate".

This time what happened? The truck attempted to cross the bridge but did not make it all the way across.

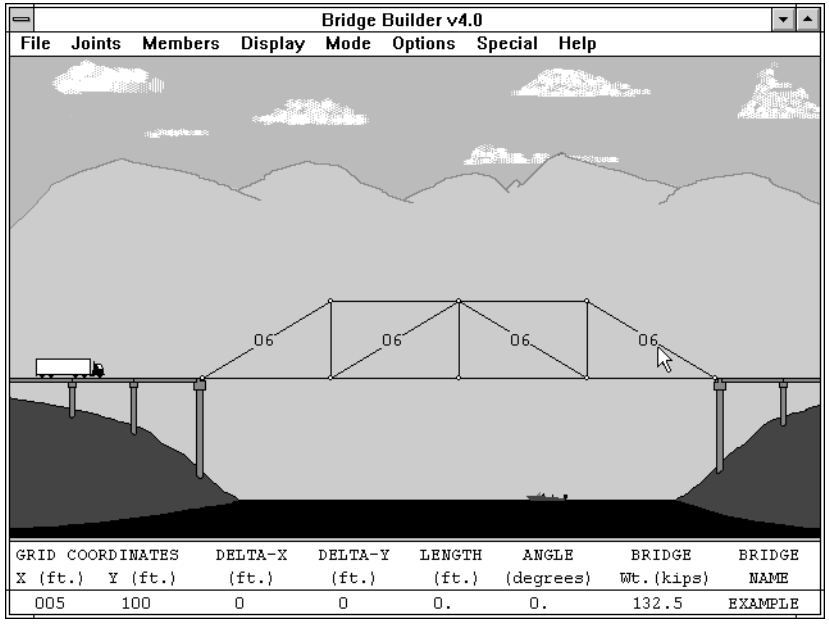
Let's take a closer look at the results to find out what we can do to get it to work.



The failed member(s) are in red. Click on the left diagonal as shown above. This is member number "4" and it is a size "5" (Refer to the "Member Library" chapter for a list of member sizes and their meaning). The actual force in the member is -116.6 kips.

The actual force is the force in the member caused by the weight on the bridge (in this case the truck). The negative sign indicates that the member is in compression.

The next category is allowable force. This member is capable of safely supporting an allowable tension force of 626.4 kips and an allowable compression force of 77.5 kips.



What can we do to get this bridge to work? Bigger members (that is a member with a larger cross section) can carry more load. Let's increase the size of the failing members. Select "6" from the "Change Size" popup menu. Next, click on the diagonal members shown above to change their size. Save this bridge.

Now select "Animate" once again from the "Mode" menu.

This time the bridge does not fail and the truck makes it across the bridge.

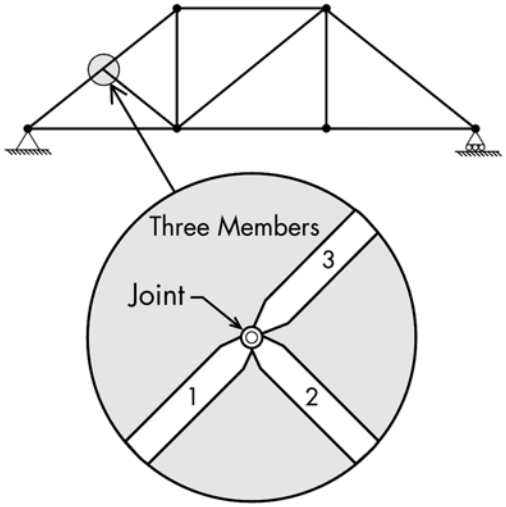
Can you build a lighter bridge ?

IMPORTANT POINTS TO REMEMBER

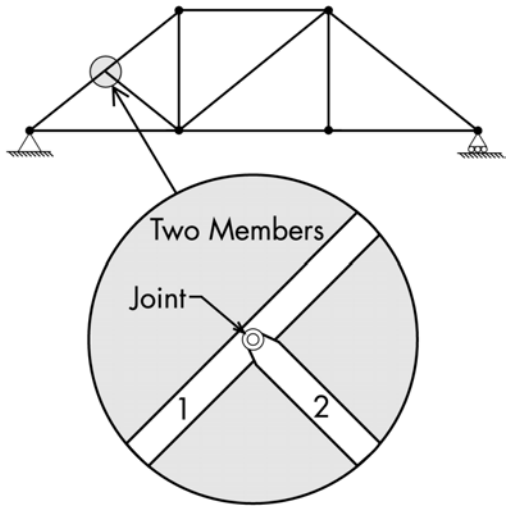
Your bridge should only touch the left and right abutments at one point - the abutment corner points. These are the points where the hinge and roller have been provided to connect your bridge to the abutments.

Also note that a flat and level roadbed should be provided for the truck to drive on. The maximum number of joints per bridge is 60 (and no more than 30 joints can lie along the roadbed), and the maximum number of members per bridge is 150. No member can exceed 130 feet in length.

Members must be connected at their end points. See the illustrations below:



CORRECT CONNECTION
(Joints must be located at every intersection of the members and only at the ends of members)

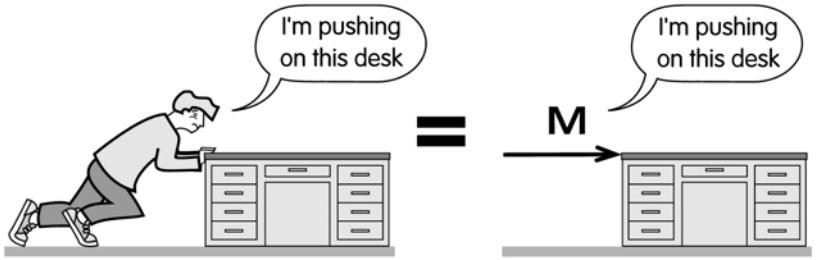


INCORRECT CONNECTION
(A member cannot intersect another member unless the intersection occurs at the end of the affected members.)

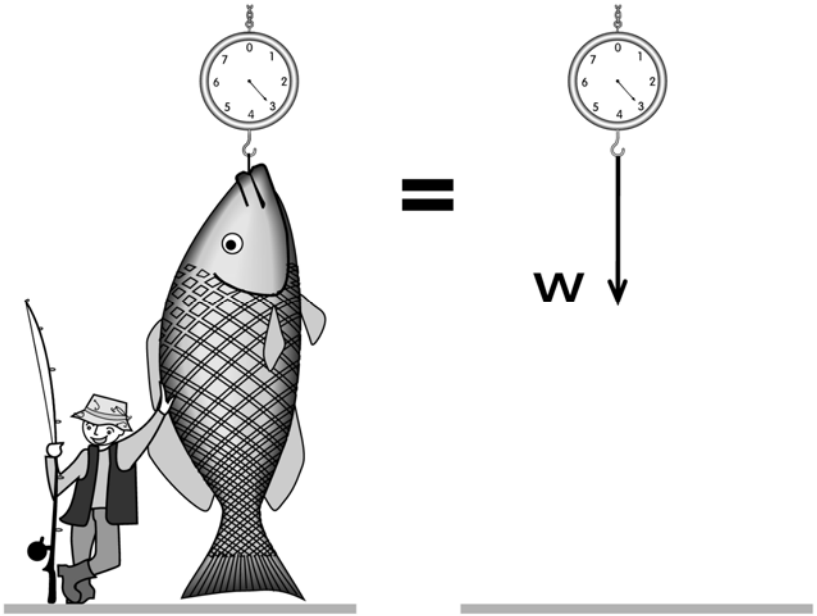
Note:

If you draw a new member and end it on an existing member, Bridge Builder will automatically make a correct connection of the resulting three members.

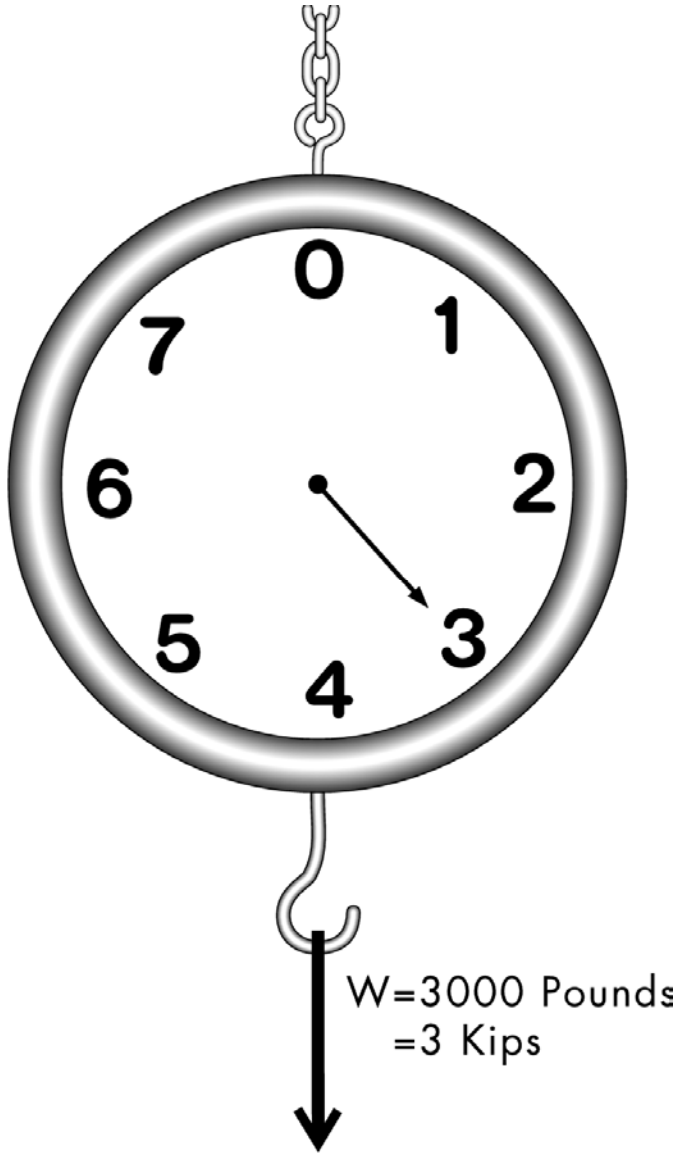
HOW ENGINEERS THINK ABOUT FORCES



Engineers represent forces with arrows. The arrow must show both magnitude (M) and direction.

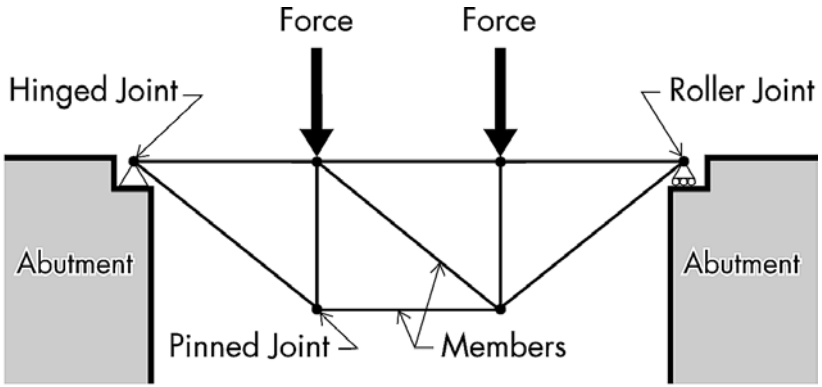


Weight (W) of an object is a force directed toward the center of the earth.



Forces are sometimes measured in pounds or kips.
1 kip = 1000 pounds

BRIDGES



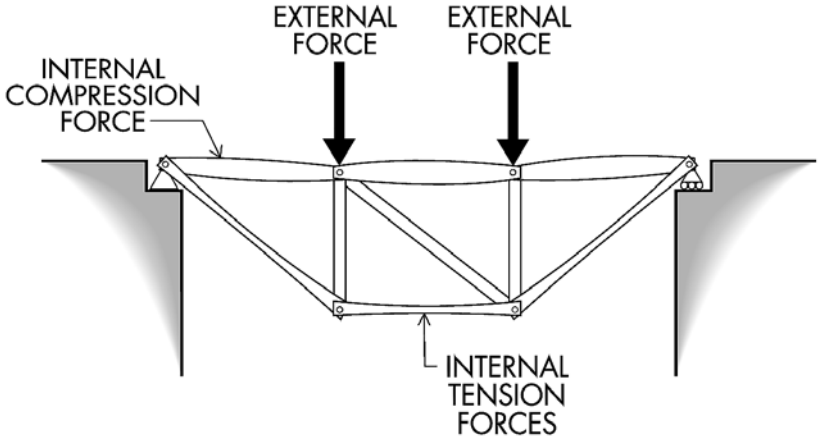
Truss Bridge

There are many types of bridges. Bridge Builder is a program about truss bridges. Bridges support forces such as the weight of trucks and cars. The elements of a truss bridge are:

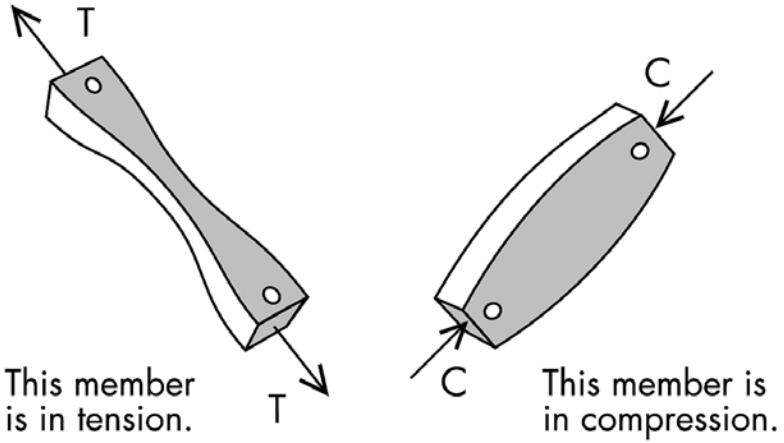
* Abutments - supports at the ends of the bridge.

* Members - framework of the bridge truss.

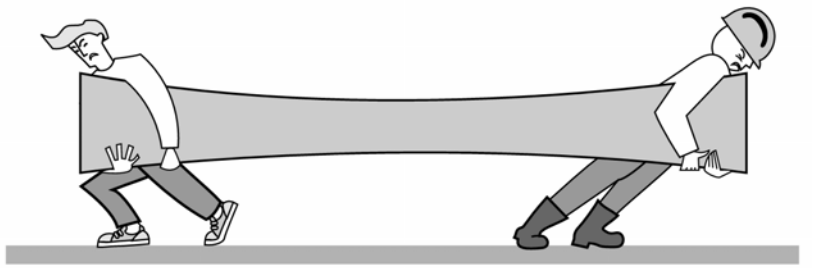
* Joints - connect the members together and connect the bridge truss to the abutments. Bridge Builder uses pinned joints, which are like single metal rods through the ends of the members, to connect the members together (see the "Important Points to Remember" chapter for a picture of a pinned joint). Bridge Builder also uses a hinged joint at the right abutment connection. The roller joint allows the bridge to expand on hot days and contract on cold days.

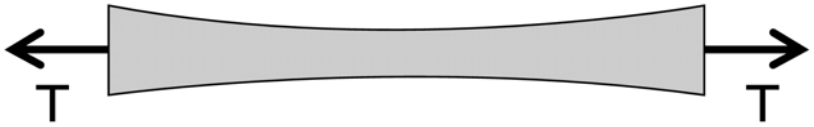


The external forces on the bridge create two basic types of internal forces in the bridge members. These two internal forces are tension and compression.



TENSION FORCES

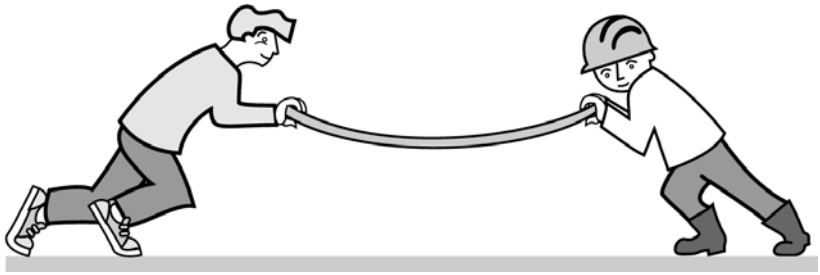




Tension forces try to pull things apart.

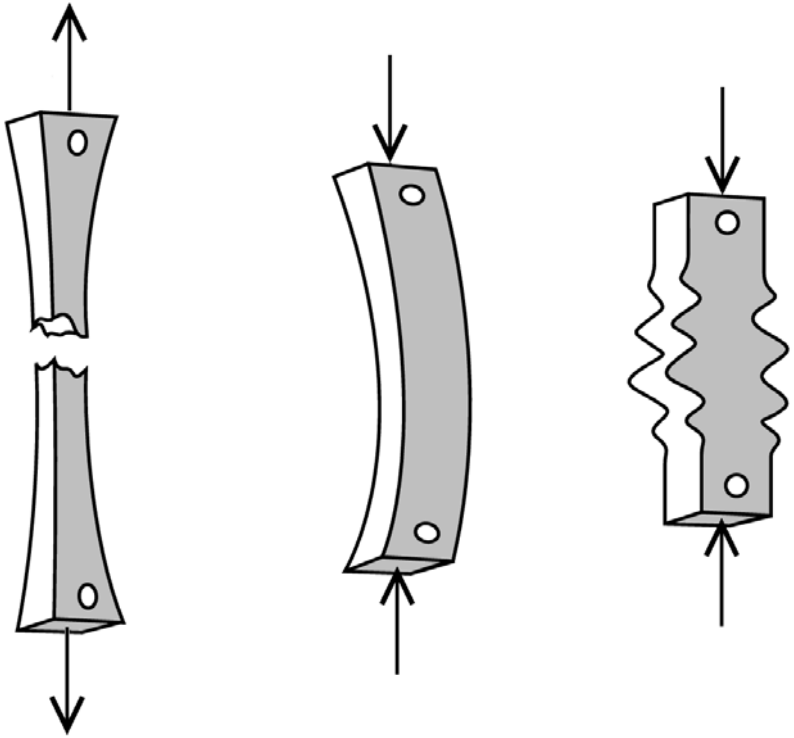
COMPRESSION FORCES

Compression forces try to crush things.



Compression forces also try to warp or buckle things.

FAILURE MODES

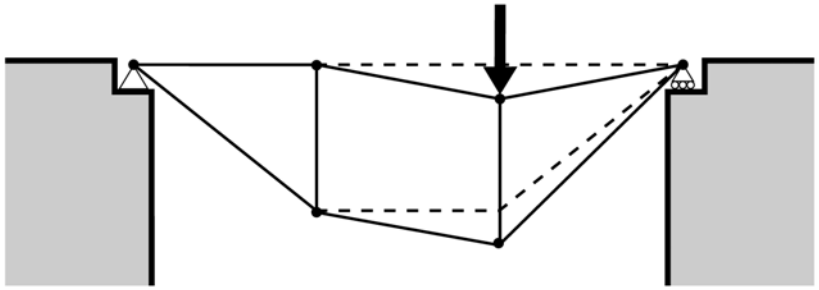


Pulling Apart | Buckling | Crushing

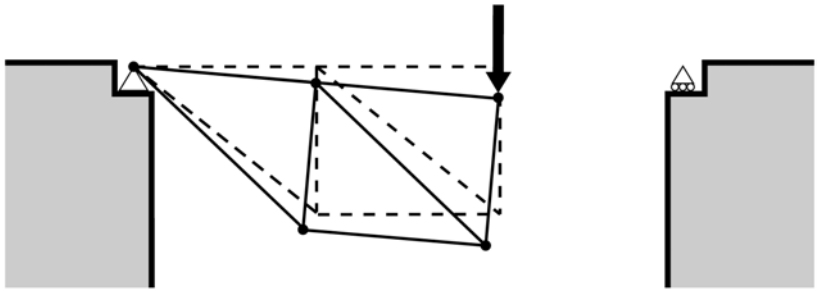
If a bridge's members pull apart, buckle or crush due to overload the bridge will collapse. The bigger the size of a member, the less the chance of overload. In other words, the heavier the member, the stronger the member.

Individual member failure is not the only reason a bridge can fail. The bridge might fail because it is unstable.

There are two possible types of geometric instability in a truss bridge:



First, a truss bridge will fall down if it is not made of triangles. These bridges are called "internally unstable".



Second, a bridge will fall down if it is not supported by both abutments. These bridges are called "externally unstable".

MENU OPTIONS

File

New, Open..., Save, Save As..., Print..., Print Setup..., Exit

New

Use this option to erase the current bridge and start a new one. If the current bridge has been changed, you will be given a chance to save it.

Open...

This option performs the same function as the "New" option listed above. In addition, this option brings up a dialog box for selecting an existing bridge from the library.

Save

Use this option to save a bridge that has previously been saved with the "Save As..." option. If this option is selected before using "Save As...", it will default to "Save As...". If a bridge already exists with this name, a replace option will be given.

Save As...

Use this option the first time you save a newly constructed bridge or when you want to change the name of the current bridge. Before typing the filename, double click on the "Library" folder. The "Library" is the subdirectory where the bridge files should be saved.

Print...

The information contained in the printer output depends on the current "Mode" of the program. See the "Mode" menu. When Bridge Builder is in the "Build" mode the printout includes a picture of the bridge along with detailed member and joint information. When Bridge Builder is in the "Review" mode the printout includes a picture of the bridge and the results of the latest analysis.

Exit - Bridge Builder

This option exits Bridge Builder and returns control to Windows. If you have a current bridge that has changes and has not been saved, you will be given the chance to save your work.

Joints

Delete, Move, Show

Delete

Use this option to delete joints (member connections). First select the "Delete" option, then click the left mouse button with the cursor arrow over the joint. When a joint is deleted, all members connecting to that joint are also deleted. Exit this mode by selecting the "Build" option under the "Mode" menu.

Move

To move an existing joint, select this option then drag the joint to a new location. You may drag a joint over the top of another. Bridge Builder will automatically erase one joint and reconnect the members to the remaining joint. To exit this option, select the "Build" option.

Show

Use the "Show" option to check the location (X,Y coordinate) of a joint. Select the option then click the left mouse button with the mouse cursor over the joint. To scroll through the joints, click away from the joints. Exit this option by selecting the "Build" option under the "Mode" menu.

Members

Delete, Change Size, Show Sizes, Default Size, Number Members, Reflect Member, Show Stats

Delete

Use this option to delete members. First select the "Delete" option, then click the left mouse button with the cursor arrow over the member. When a member is deleted, the remaining members are renumbered. Exit this mode by selecting the "Build" option under the "Mode" menu.

Change Size

To change the size of a member, select this option from the pull down menu and the new size from the associated pop up menu. Position the mouse cursor over the member you wish to change then click the left mouse button. The new size of the member will be printed at the center of the member to confirm the change. You may continue changing members to this new size by pointing and clicking. Exit this option by either selecting another option or selecting "Build" from the "Mode" menu.

Show Sizes

This option allows viewing of all member sizes at once. Exit this option by selecting another option or selecting "Build" from the "Mode" menu. You may clear the screen by selecting "Refresh" from the "Display" menu.

Default Size

When you draw a new member, a default member size is automatically used. To change the default member size, select this option from the "Member" pull down menu. Next, select the new default member size from the associated pop up menu.

Number Members

Use this option to place the number assigned to each member at the center of the member for reference purposes. You may clear your screen by selecting "Refresh" from the "Display" menu.

Reflect Member

This is a drawing assist option. To make a mirror image of a member across the mid-span of the bridge, select this option and click the left mouse button with the cursor over the member. Members that straddle the mid-span of the bridge cannot be reflected. Members that just touch the mid-span of the bridge can be reflected. To exit the option select another option or select "Build" from the "Mode" menu.

Show Stats

Use this option to display member information in the display at the bottom of the window. Select the option, then position the mouse cursor over the member and click the left mouse button. Exit this option by selecting another option or by selecting the "Build" option from the "Mode" menu.

Display

Grid, Refresh, Reset Window, Joint Snap, Coordinate Snap

Grid

Select this option to toggle the grid. The grid points will roughly match the current coordinate snap settings.

Refresh

Use this option to clear the screen after using selected member options.

Reset Window

This option will reposition the window to its default location. The window should not be reduced or expanded when using the "Build" mode. Select this option to properly size the window for the "Build" mode.

Joint Snap

This is a drawing assist option. This option sets the size of the hot zone around an existing joint. When drawing a new member the program will find an existing joint if the end of the member is placed in the joint's hot zone.

Coordinate Snap

This option changes the incrementing of the X,Y coordinate readout at the lower left corner of the window from a default setting of 5 to 1, 2, 4, or 10.

Mode

Build, Calculate, Animate, Review

Build

The program must be in this mode to add members to your bridge. Also, you may want to select this mode as a means for exiting other options.

Calculate

Select this option to calculate the results without having the truck drive across the bridge. That is, this mode analyzes the bridge without running the animation.

Animate

This option not only analyzes the bridge, it also animates the results. The truck attempts to drive across the bridge and if the bridge is not of adequate strength, the bridge collapses into the river.

Review

This mode is for viewing the results of the latest analysis. This mode is automatically entered after analysis. To exit this mode select the "Build" "Mode" from this menu.

Options

Include Truss Dead Load, Include Deck Weight, Include Max. Traffic Load, Use Min. Member Force

Include Truss Dead Load

Use this option to add realism to the Bridge Builder simulation. With this option, the actual weight of each truss member is added into the calculations when determining the actual forces in the members. The larger the member size chosen, the more weight the bridge must support.

Include Deck Weight

This is another option intended to add realism to the program. Selecting this option adds the actual weight of the bridge deck to the analysis.

Add Max. Traffic Weight

This is another option intended to add realism to the program. Selecting this option adds the equivalent weight of a bridge full of trucks, bumper to bumper, stopped on the bridge, to the analysis.

Use Min. Member Force

This is another option intended to add realism to the program. Selecting this option sets a minimum design load of 6 kips for a member of the bridge.

Special

Make DXF, Make VRML, Copy to Clipboard, Use Sound

Make DXF

Use this option to send a drawing of your bridge to another CAD or drawing program. DXF stands for **D**rawing e**X**change **F**ile.

Make VRML

Want to see a 3-D model of your bridge? This option creates a ".wrl" file that can be displayed by many VRML enhanced Internet browsers or viewers. You can view these files from your Internet page or from your own hard drive.

Copy to Clipboard

This option copies the current bridge drawing to the Window's clipboard. You can then use the paste command from other applications to insert the drawing of the bridge into notes or reports.

Use Sound

If your system has an MCI compatible sound card you may select this option to toggle the sound option on and off.

Help

Getting Started, Menu Options, About...

Getting Started

This is where to look if you don't know what to do next. This option will give you a brief description of how to design and test a bridge using Bridge Builder.

Menu Options

You used the menu to access this help file. This file contains information about the menu options and their use.

About...

The purpose of this notice is to inform you that Bridge Builder is a copyrighted software package and its use is subject to federal and international laws and treaties. It is unlawful to copy any part of this software (disk media or written manual) without the written permission of the owner.

Note:

To clear a pull-down menu, click the left mouse button with the arrow located off of the grid area. Clicking on the grid will cause the start of a new bridge member.

INTERPRETATION OF RESULTS

This chapter discusses the numerical results of the analysis. Results are available after calculation or animation. Click on a bridge member to list the results for that member at the bottom of the window. No numerical results are possible for unstable bridges.

If your bridge has stable geometry, the following results are available for each member:

Member # - This number is used to identify the member on the picture of the bridge when results are printed. The member # is assigned as each member is drawn. When a member is deleted, the member numbers are adjusted accordingly.

Size # - This number represents the size of the member as described in the chapter entitled "The Member Library".

Length - This is the length of the member in feet from the starting joint to the ending joint as measured along the member.

Actual Force - The actual force is the maximum force (tension or compression) generated in the member by the truck driving across the bridge plus any additional load specified under the "Options" menu. If the actual force is negative, the member is in compression. If it is positive, the member is in tension. The member will fail if the *absolute value* of the actual force is greater than the corresponding *allowable force*.

Allowable Force - The allowable force is the maximum force that the individual member is capable of carrying by virtue of its size and length. The larger the member size, the more force the member can carry. Of course bigger members weigh more. When comparing this force to the actual force, use the allowable compression force if the "actual" force is negative. Use the allowable tension force if the actual force is positive (no negative sign).

Efficiency Ratio - This number is calculated by dividing the actual force (disregarding its sign) by the corresponding allowable force and then multiplying this quantity by one hundred to change it to a percentage. The efficiency ratio represents the degree to which you are effectively using the strength of the member.

For example, if the ratio is 50%, the member is stressed to half of its potential strength. Efficiency ratios near 100% represent excellent use of a member's available strength.

The efficiency ratio will be replaced by the word "FAIL" if the actual force is greater than the allowable force.

Note:

Some bridge geometries have members that do not appear to be serving any purpose because they carry no load (actual force = 0). These members may be adding stability to the structure by preventing other members from buckling. These members are called "Zero Force Members".

PRINTER OUTPUT

Printer Output

The Bridge Builder results can be output to any Windows® compatible printer. The information printed will depend on the "Mode" that the program is in. If the program is in the "Review" "Mode" the information printed will be the results of the analysis. When the program is in the "Build" "Mode" the printout will contain member and joint information corresponding to the bridge design.

Printout From the Review Mode

The printout from the "Review" "Mode", labeled "RESULTS", contains a picture of the bridge and the information provided at the bottom of the window plus the following:

- Angle - The orientation of the member measured clockwise from a right extending horizontal.
- Bridge name and weight
- Overall efficiency ratio of the bridge
- Options used.
- Total number of joints and members
- Maximum downward deflection of the truss.

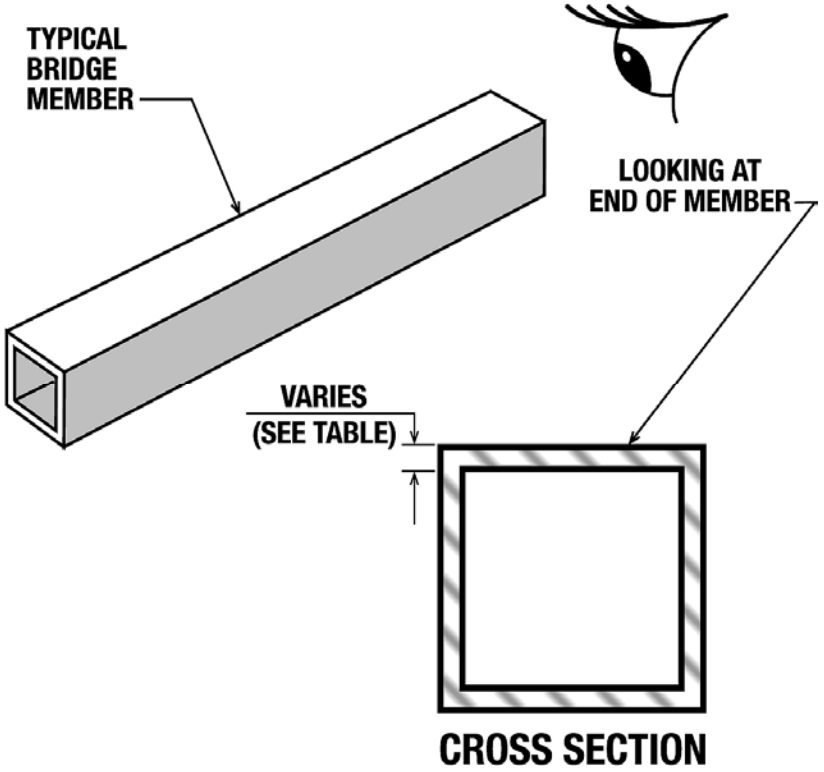
Printout From the Build Mode

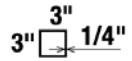
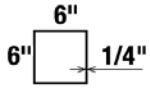
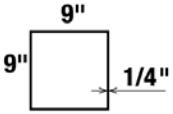
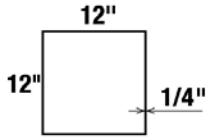
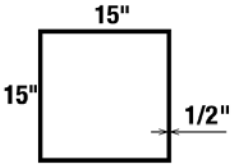
The printout from the "Build" "Mode", includes a drawing of the bridge plus additional member and joint information not available when printed from the "Review" "Mode". The additional information is listed below:

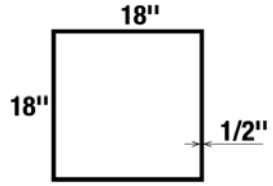
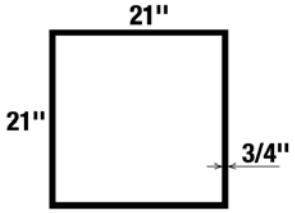
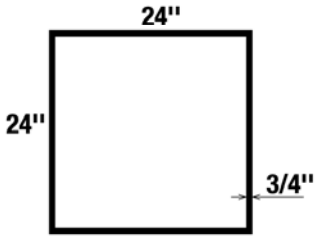
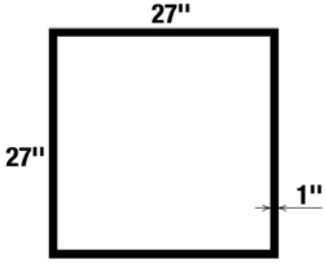
- Joint Coordinates - The location of the connections given in Cartesian coordinates
- Joint Type - 1 = Normal connections (not a hinge, roller or roadbed)
  2 = Hinge connection at the left abutment
  3 = Roadbed connections
  4 = Roller connection at the right abutment
- Dead Load - That portion of the truss self-weight to be applied at that joint (connection).
- Deck Load - That portion of the concrete road, floor beams and stringer weight to be applied at that joint.
- Traffic Load - Additional load added to the bridge to simulate bumper to bumper truck traffic.
- Jt1 # - The starting joint of the member.
- Jt2 # - The ending joint of the member.
- Self-Wt. - Actual weight of that truss member.
- Deck-Wt. - "Deck Load" between Jt1 & Jt2.
- Traffic - "Traffic Load" between Jt1 & Jt2.

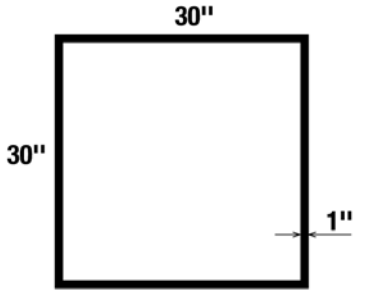
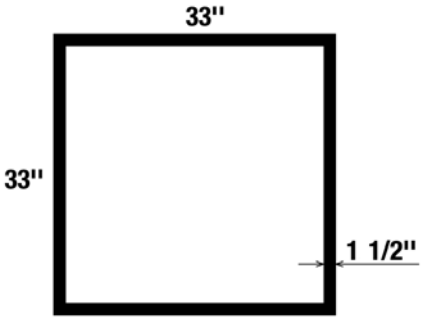
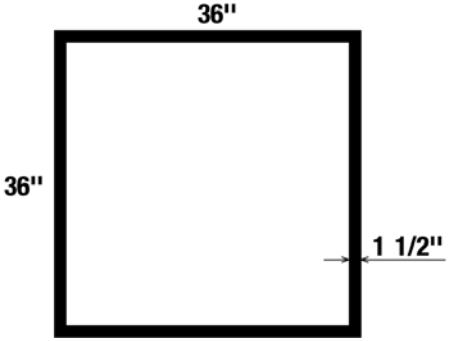
THE MEMBER LIBRARY

To build your bridge, select members from the library on the next three pages. All of the members have a square hollow cross section and are made from steel plates. The thickness of the steel plate is noted.



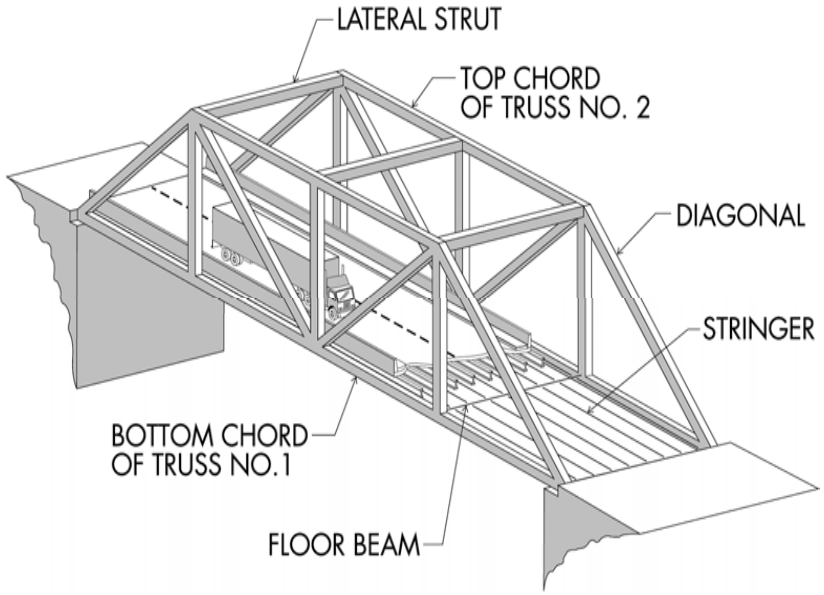
Size #	Cross Section (in. x in.)	Cross-Sectional Area of Steel (in^2)
1		2.75
2		5.75
3		8.75
4		11.75
5		29.0

Size #	Cross Section (in. x in.)	Cross-Sectional Area of Steel (in^2)
6		35.0
7		60.75
8		69.75
9		104.0

Size #	Cross Section (in. x in.)	Cross-Sectional Area of Steel (in^2)
10		116.0
11		189.0
12		207.0

THE STRUCTURAL SYSTEM

The Bridge Builder gameboard is two dimensional. In other words, you can see the length and the height of the bridge, but you cannot see the width of the bridge or the roadway that it supports. Take a look at the three dimensional picture of the bridge below. Now you can see the width of the roadway and the structural system (the structural system is the path that the load (of the truck) uses to reach the truss and ultimately the abutments).



Here's how the weight of the truck gets to the truss. Assume the a truck is positioned between two floor beams as shown above (two transverse beams - one just behind the vehicle and one in front of the vehicle).

The weight of the truck travels along the floor slab into the stringers then along the stringers into the floor beams. Then the floor beam delivers the weight of the truck into the truss at a joint. Note that the bottom chord of the truss never gets any of the direct weight of the truck. Therefore, the bottom chord only experiences an axial load (load directed along the axis of the member) of either tension or compression.

In Bridge Builder, you are designing one of the two identical trusses that carry the load into the abutments. Each bridge truss must be capable of supporting an 80,000 pound truck plus any additional load that you have specified in the "Options" menu. The weight shown on the "Build" screen is actually the weight of one of these two identical bridge trusses.

TECHNICAL SUPPORT

We are always looking for ways to improve our product. If you have any questions, concerns or suggestions, please do not hesitate to call or email.

Phone: (225) 769-3728
Fax: (225) 769-3661
E-mail: mail@ pre-engineering.com
URL: http://www.pre-engineering.com